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Investigations on the chemical and bioactivity profile of Bromeliaceae Juss

Investigações sobre o perfil químico e de bioatividade de Bromeliaceae Juss

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ABSTRACT
Bromeliaceae Juss., in several cultures for thousands of years it has been used for food, fibers, in ceremonies, medicines and ornamental plants. The phytochemical composition of the species of the family is chemodiverse, with the presence of fatty acids, phenolic compounds, vitamins, triterpenes and enzymes, exerting antibacterial, antimicrobial, hypoglycemic, antileukemic, proteolytic activities, non-polar natural products and production of bioactive peptides. As a result, the family has great chemical and pharmacological potential in order to contribute to scientific knowledge and the development of new drugs.

Keywords: bromeliads, chemodiversity, flora, uses.

RESUMO
Bromeliaceae Juss., em diversas culturas há milhares de anos tem sido utilizada como alimento, fibras, em cerimônias, medicamentos e plantas ornamentais. A composição fitoquímica das espécies da família é quimiodiversa, com presença de ácidos graxos, compostos fenólicos, vitaminas, triterpenos e enzimas, exercendo atividades antibacteriana, hipoglicêmica, antileucêmica, proteolítica, produtos naturais apolares e produção de peptídeos bioativos. Como resultado, a família possui grande potencial químico e farmacológico para contribuir com o conhecimento científico e o desenvolvimento de novos medicamentos.

Palavras-chave: bromélias, quimiodiversidade, flora, usos.

1 INTRODUCTION

The family Bromeliaceae Juss., has been gaining prominence due to its biological potential and has been the target of chemical studies allowing the isolation and identification of compounds, among them, different types of flavonoids, terpenes, steroids, phenylpropanoids, such as cinnamic acid and phenolic compounds (Manetti et al., 2009; Vasconcelos, 2013). The most chemically studied species of this family is *Ananas comosus* (L.) Merr, (pineapple) due to the commercial value of its juice, one of the most consumed in the world. Commonly, some species of this family are used for the

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production of fibers, human and animal food, as fuel and with emphasis on their medicinal potential, such as antimicrobial, anti-inflammatory, antioxidant, hypoglycemic activity, among others.

Chemical characterization and bioactivity are important approaches in the discovery of new drugs, considering that Brazil provides natural resources to obtain drugs, and with the diversity of bromeliad species, there is pharmacological potential for the discovery of new secondary metabolites, which justifies the interest in the study of species of this family. The present review aims to synthesize the main chemical, pharmacological and biological aspects of species of this family, indicating the pharmacological and biological action of bromeliads described in the literature, providing a better exploration and application of the species.

2 MATERIALS AND METHODS

The method used in the Review was Cooper's Taxonomy (1988) updated by Randalph (2009) and adapted by Ferreira, Silva and Cantuária (2022), and is classified as follows: (1) Focus: results of research involving "Bromeliaceae", "Bromeliad", "phytochemicals", "pharmacological activities", "medicinal chemistry", "secondary metabolites", "ethnopharmacological" and their practices and applications; (2) Objective: generalization; Perspective: neutral representation; Coverage: exhaustive (for Bromeliaceae and phytochemistry) and representative (for secondary metabolites of bromeliads); (3) Organization: conceptual; (4) Target audience: general and specialized scholars. To compose a checklist of the chemical compounds of bromeliads.

The following search tools were used to investigate publications: PubMed, Science Direct, Periodicals Capes and Google Scholar. The search period comprised the years 2020 to 2022, in English and Portuguese. Exclusion criteria were articles that did not present any aspect of the proposed theme or that were written in languages other than those mentioned above, as well as the results of theses and dissertations. The nomenclature of the organisms cited in the study followed the indications in the codes in force (Cantuária et al., 2022) and Brazil Flora Group (BFG, 2022).

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3 RESULTS AND DISCUSSION

Bromeliads have been consumed by the American peoples since pre-Hispanic times, in various cultures, Aztecs, Mayans, Incas, Quechuas, Yanomami and other peoples, used them for food, fiber, ceremonies, medicines and ornamental plants (Benzing, 2000; Pierce, 2000) as they are still used today, where the main forms of use as a food source include the whole fruit or another part of the plant (Table 1). In India, pineapple peel juice is used for the treatment of urinary tract diseases (Sen et al., 2018), aids in wound healing (Prakoso et al., 2018). In China, the fruit is used to relieve yellow fever, obesity, prevent cancer, and maintain vitamin C levels and the leaves are used to relieve coughs and jaundice (Emmanuel; Didier, 2012). In Brazil, the peels and fruit are used for urinary tract infections as a depurative, diuretic, and for general respiratory problems (Santos et al., 2023).

Table 1. Tradicional uses of Bromeliaceae species.

Genera	Tradicional uses	Plant part used	Reference
Ananas Mill.	Abortive, asthma, bronchitis, cough, diuretic, fever, hemorrhage, kidney stone treatment, malaria, prostate, sore throat, vermifuge, whooping cough and wound healing.	Bark, Fruit, Leaves and Root	Emmanuel; Didier, 2012; Sen et al., 2018; Prakoso et al., 2018; Santos et al., 2023.
Bromelia *L.*	Asthma, bronchitis, diabetes, diarrhea, diuretic, fever, hepatitis, icterus, cough, vermifuge, kidney stone treatment, scurvy and whooping cough.	Fruits and Roots	Reitz, 1983; Jorge; Ferro, 1993; Romero-Garay et al., 2018.
Neoglaziovia Mez.	Cough, bronchitis, *grippe and pneumonia.*	Fruits	Paula; Guarconi, 2007.
Nidularium *Lem.*	Antiallergic, anti-inflammatory, analgesic and diuretic.	Leaves	Chedier et al., 2000; Vieira-de-Abreu et al., 2005.
Tillandsia L.	Arthritis, bronchitis, burns, diabetes, diuretic, lung diseases, gastritis, hemorrhoids, eye infections, laxative, rheumatism, cough, ulcers.	Aerial parts	Reitz, 1983; Witherup et al. 1995; Mors et al., 2000; Sandoval-Bucio et al., 2004; Hornung-Leoni, 2011; Mondragon et al., 2011.
Hechtia Klotzsch	Bronchitis, *diabetes*, diuretic, cancer, respiratory infections and kidney problems.	Leaves	Sandoval-Bucio et al., 2004; Hornung-Leoni, 2011; Mondragon et al., 2011.

Source: Authors (2023).

In Brazil, *Bromelia antiacantha* Bertol., the fruits are used as an expectorant in respiratory infections, against asthma, cough and bronchitis, they are used in cases of

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canker sores and wounds, diuretic, fever, dewormer and in the treatment of kidney stones (Reitz, 1983; Jorge; Ferro, 1993; Dorigoni et al., 2001). In Mexico, the fruits of *Bromelia pinguin* L., are used as dewormers, diuretics, abortifacients, in the treatment of pertussis, scurvy, diabetes, kidney diseases and in the relief of respiratory diseases (Reitz, 1983; Argueta; Gallardo, 1994; Paula; Guarconi, 2007). In Brazil, *Neoglaziovia variegata* (Arruda) Mez, the fruit tea is used in the treatment of cough, bronchitis, flu and pneumonia (Paula; Guarconi, 2007). *Nidularium inocenteii* Lem., the leaves are used for anti-inflammatory, analgesic and diuretic treatment (Chedier et al., 2000). Mexico, *Tillandsia recurvata* (L.) L, used in the treatment of burns, rheumatism, ulcers, hemorrhoids, cough and bronchitis (Sandoval-Bucio et al., 2004; Vieira-de-Abreu et al., 2005; Hornung-Leoni, 2011). In the United States *Tillandsia usneoides* (L.) L., tea made from this species is used to relieve the symptoms of diabetes mellitus (Witherup et al., 1995). In Mexico, *Hechtia glomerata* Zucc, used for colds and bronchitis (Mondragon et al., 2011).

The phytochemical composition of the species of the Bromaliaceae family is chemodiverse, with the presence of phenolic compounds, Steroid/Triterpene, Monoterpene, Fatty Acids, Flavonoids, described in (Table 2, Figure 1) potentially beneficial to health.

Table 2. Chemically defined molecules of Bromeliaceae.

Species	Class of Meta-bolyte	Nº	Chemical substance	Referência
Ananas comosus (L.) Merr	Sterols	1	*β*-Sitosterol	Rodrigues et al., 2020
		2	Stigmasterol	
	Phenolic acid	3	*p*-coumaric acid	
Bromelia karatas L.	Monoterpene	4	2-Heptanol, 5-ethyl	Ayil-Gutiér-rez et al., 2022
		5	2 (3H)-Furanone	
		6	Thymol	
		7	5-hydroxymethylfurfural	
		8	2-Methoxy-4-vinylphenol	
Bromelia laciniosa Mart. ex Schult. & Schult.f.	Steroidal aglycones	1	*β*-Sitosterol	Pontes et al., 2022
		2	Stigmasterol	
	Flavona	9	Cirsilineol	
	Fatty acids	10	Hexadecanoic acid	
		11	(9Z)-Octadec-9-enoic acid	
	Triterpenoids	12	Campesterol	
	Steroid/Triterpene	13	Cyclolaudenol	

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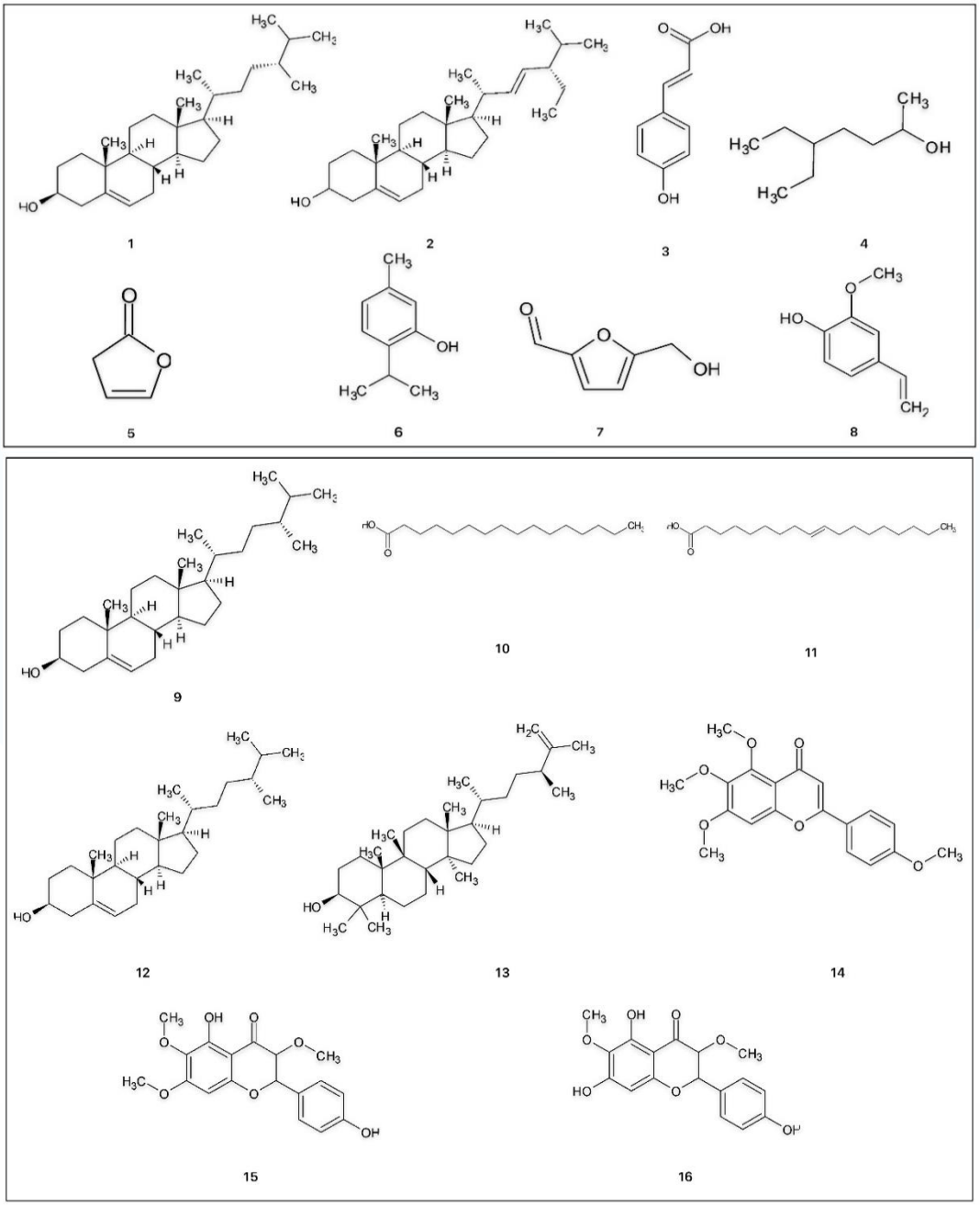
Nidularuim procerum Lindm.	Flavonoids	14	5,6,7-trimethoxy-2-(4-methoxyphenyl)chromen-4-one	Gollo et al., 2020
Tillandsia bergeri Mez	Flavonoids	15	Penduletina	Lo et al., 2022
		16	Viscosine	

Source: Authors (2023).

Figure 1. Chemical structures of the species of the Bromeliaceae family.



Source: Authors (2023).

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The phytochemical study of *A. comosus* was carried out through chromatographic analysis associated with the UV spectrum in the leaves, isolating three substances: *β*-sitosterol and a mixture of stigmasterol in the dichloromethane and hexane extracts, and *p*-coumaric acid in the ethyl acetate extract. The isolated *p*-coumaric acid showed a high ovicidal effect against goat gastrointestinal nematodes. The study revealed for the first time that *A. comosus*, which can be considered the active substance of ethyl acetate, has inhibitory activity against gastrointestinal nematodes with *Haemonchus* Cobb, 1898, *Oesophagostomum* Molin, 1861 and *Trichostrongylus* Looss, 1905, and that *p*-coumaric acid is an important bioactive (Rodrigues et al., 2020).

The metabolic composition of *B. laciniosa* was analyzed by mass spectrometry and liquid chromatography, and a total of thirty-nine chemical constituents were identified for the first time. The study found that the ethanolic extract of the leaves inhibited the growth of *Staphylococcus aureus* Rosenbach, 1884, at the lowest concentration evaluated. The results show the diversity of secondary metabolites, such as Stigmasterol, *β*-Sitosterol, Hexadecanoic Acid, 9-Octadecenoic Acid (Z), *α*-Tocopherol, and Campesterol (Pontes et al., 2020).

In some studies, attention has been paid to the analysis of phytochemical composition and bioactivity. The use of hyphenated techniques to determine the metabolomic profile of plants, however, has been limited to a few studies. The methanolic extract of *B. karatas*, fruit juice, contained 131 compounds, some of which had already been reported to have biological activities, such as bactericidal, fungicidal, anticancer, anti-inflammatory, enzyme-inhibiting and anti-allergic properties. The most abundant compounds found in the methanolic extract of the fruits were maleic anhydride, 5-hydroxymethylfurfural and itaconic anhydride. The study shows that fruits contain metabolites that are potentially beneficial to health (Ayil-Gutiérrez et al., 2022).

A phytochemical investigation led to the isolation and identification by high-resolution mass spectrometry and nuclear magnetic resonance of the two flavones penduletin and viscosine, compounds identified from the diclomethane extract, responsible for the antibacterial activity of *T. begeri* (Lo et al., 2022).

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Phytocompounds have been found in *N. procerum* through Gas Chromatography–Mass Spectroscopy (GC-MS), a total of 43 compounds belong to different chemical classes, including hydrocarbons, fatty acid esters, steroids/triterpenes, aldehydes, amides, vitamins, and combones (Gollo et al., 2020).

Several species of bromeliads, especially the *genus Ananas* Mill., are used as medicine, the study shows the potential of new drug sources, revealing biological and pharmacological properties, which include Antibacterial (Lo et al., 2022), Anticancer (Rodrigues et al., 2021), Antidiabetic, Anti-inflammatory (Oso et al. 2022), Antimicrobial (Pontes et al., 2022), Antioxidant Gomes et al., 2022), Gastroprotective (Lira et al., 2021), among other studies.

3.1 *Ananas comosus* (L.) MERR.

They investigated in *vitro* anthelmintic activity of extracts and fractions of the leaf of *A. comosus* against eggs and infective larvae of gastrointestinal nematodes Trichostrongylidae Leiper, 1908. The study revealed inhibitory activity against gastrointestinal nematoies against *Haemonchus* Cobb, 1898, *Oesophagostomum* Molin, 1861, and *Trichostrongylus* Looss, 1905. P-coumaric acid alone had a high effect on goat gastrointestinal nematodes (CI50: 0.12 mg mL− 1). Leaf fractionation showed high antioxidant activity (EC_{50} for DPPH of 2.16–21.38 mg mL^{-1} and inhibition of β-carotene cooxidation of 36.40–74.86%) and anthelmintic activity (15.69–100% inhibition of egg hatching), ethyl acetate extract exhibited higher activity in all assays (Rodrigues et al., 2020).

Evaluation of the antioxidant activity of the crude extract of *A. comosus* leaves. The study shows a high antioxidant activity observed in hydroalcoholic extracts, when compared to other extracts, revealing the presence of secondary metabolites such as alkaloids, glycosides, *phlorotannins*, *tannins* and flavonoids, indicating that the leaf extract can be used as an antioxidant and also as a memory enhancer (Sahu et al., 2020).

They evaluated the prophylactic role of the ethanolic extract of *A. comosus* against sodium oxalate-induced nephrolithiasis (NaOx). The extract showed a beneficial effect in preventing stone formation, significant reductions in urinary and serum excretion of

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calcium and phosphate were obtained, along with an increase in magnesium excretion in treated *urolithiasis* rats, significantly attenuating NaOx-induced oxidative damage. The extract has antilithiatic efficacy may be due to its diuretic activity, antioxidant activity, in addition to its bioactive constituents that affect calcium oxalate crystallization (Sayed et al., 2020).

They evaluated the antimalarial effect of *A. comosus* extract and fractions in mice and identified bioactive compounds. The results showed that the extract and all its fractions and subfractions showed significant inhibition ($p < 0.05$) of parasitemia. Gas chromatography-mass spectroscopy (GC-MS) analysis revealed the presence of 17 bioactive compounds, the most abundant of which are fatty acids, linoleic acid, and palmitic acid (Uzor et al., 2020).

They investigated the atheroprotective role and neuroprotective effects of the methanolic aqueous extract of *A. comosus* in normal diet and high-fat diet fed to rats. As a result, the extract significantly attenuated the reduction induced by a high-fat diet in the correct alternation in the Y-maze test and in the discrimination index in the recognition of new objects. It demonstrated anxiogenic activity and significantly improved lipid profile and decreased the risk of atherogenicity in rats fed a normal diet and a high-fat diet and serum and brain antioxidant status by decreasing malondialdehyde and increasing GSH and catalase (Ajayi et al., 2021).

They evaluated the attenuating effects of raw A. *comosus* juice on obesity-associated testicular impairment in rats. Administration of raw pineapple juice to obese rats significantly reduced spermatogenic cell degeneration and NF-κB and Caspase-3 immunoreactivity. In addition, treatment with the juice significantly increased immunoreactivity to PCNA in obese rats. Treating obese rats with pineapple juice restored testicular homeostasis, indicating its potential validity for overcoming obesity-induced male fertility disorders (Alkafafy et al., 2021).

Synthesized silver nanoparticles (AgNPs) were used from residues from *A. comosus* shells, examining their anticancer and antibacterial activities. AgNPs showed antimicrobial effects at low concentrations. To examine the usability of these particles as an anticancer agent, their cytotoxic effects were examined, and it was determined that the

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concentration of 25 µg/mL showed 25-81% inhibition in different cancer cell lines. The nanoparticles showed promising inhibitory activity in Gram-positive and Gram-negative pathogenic microorganisms: *Escherichia coli* (Migula, 1895) Castellani & Chalmers *1919* ATCC25922, *Staphylococcus aureus* Rosenbach 1884 ATCC29213, *Bacillus subtilis* ATCC11774, *Pseudomonas aeruginosa* ATCC27833 bacteria, and *Candida albicans* (C.P.Robin) Berkhout, fungi, yeast at low concentrations (Baran et al., 2021).

They unraveled the antioxidant and hepatoprotective potential of *A. comosus*, methanol bark extracts in *vivo* in albino rats and demonstrated that they can serve as main sources of alternative therapy and dietary supplements. The DPPH assay showed that the peel of the fruit presented antioxidants. The results demonstrated that bark extracts are potential alternative sources of pharmaceuticals and nutraceuticals since they exhibited strong antioxidant and hepatoprotective activities in CCl_4-induced liver damage in experimental rats (Unanma et al., 2021).

They evaluated the antimalarial, antinociceptive and anti-inflammatory properties of *A. comosus* bark extract. The extract tested mild antimalarial activity, but significant antinociceptive and anti-inflammatory properties, by inducing exudate formation, inflammatory cell count, and levels of nitrite, tumor necrosis factor-alpha, and interleukin-6 (Ajayi et al., 2022).

They investigated potential antioxidant and anti-inflammatory properties and phytochemical analyses of the methanolic extract of ripe and green bark of *A. comosus.* The estimated amounts of total flavonoids present in the ripe bark extract were significantly higher ($p < 0.05$) than those estimated in the green bark extract. The results of the study indicated that the extracts exhibited corresponding antioxidant and anti-inflammatory properties that can be attributed to characteristic phytochemical constituents. Consequently, the extract may be effective against disorders related to oxidative stress and inflammation (Oso et al., 2022).

They evaluated the potential of the ecoenzyme (EE) produced by the fermentation of residues of fruit *A. comosus*, as a source of antibacterial and antioxidant compounds. The ability of (EE) to inhibit the growth of gram-negative *Escherichia coli* (Migula, 1895) Castellani & Chalmers, 1919 and gram-positive *S. aureus* bacteria demonstrates its

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antibacterial activity. However, its efficacy was still lower than that of ciprofloxacin, a broad-spectrum antibiotic used as a positive control. The results demonstrate that (EE) has the potential to serve as a source of antibacterial and antioxidant properties (Tallei et al., 2022).

3.2 *Bromelia antiacantha* BERTOL

The objective of this study was to evaluate the phytochemical profile of aqueous and ethanolic extracts obtained from *B. antiacantha* fruits, as well as their possible antioxidant, antitumor and cytotoxic action. The aqueous extract exhibited phenolic compounds and flavonoids, while the ethanolic extracts indicated the presence of flavonoids and coumarin in their composition, regardless of the collection region. The ethanolic extract demonstrated a more promising antioxidant effect than the aqueous extract and induced a significant inhibition in the viability of human cervical cancer cells of the SiHa strain (Rodrigues et al., 2021).

3.3 *Bromelia karatas* L.

They evaluated the proteolytic activity of *B. karatas* fruits under different conditions of temperature, pH and NaCl, and estimated the thermal stability of their proteases. They found that the bactericidal activity resisted the sterilization temperature, its potential benefits are still maintained when fruits are consumed cooked, cooking is necessary to avoid oral injury caused by its proteolytic activity (Villanueva-Alonzo et al., 2019).

They studied the hypoglycemic effect of the administration of aqueous extract of *B. karatas* in STZ-NA rats and evaluated the lipid profile and glycated hemoglobin levels of the animals after chronic administration of the extract. As a result, oral administration of the aqueous extract showed a significant hypoglycemic effect, which was the result of a 42-day chronic trial. The extract was able to control the elevation of hemoglobin with no effect on cholesterol or vLDL levels. The study defends the traditional use of the plant in the treatment of type 2 diabetes and describes the compound Cirsiliol 4'-O-glucoside as a novel hypoglycemic agent (Escandón-Rivera et al., 2019).

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The behavior of the respiratory rate of *B. karatas* during storage was evaluated; the effect of the maturation stage of the fruits (green and intake) on physicochemical parameters and specific proteolytic activity was also studied, as well as the antibacterial effect of pre-purified proteases of these fruits. It showed higher specific enzymatic activity in the green maturity state, with 18.99 U/mg. Pre-purified fruit proteases showed antibacterial activity against *E. coli* and S. *aureus*, but were not heat-resistant (Montalvo-González et al., 2021).

They evaluated the bactericidal activity of the methanolic extract and its fractions (hexane, ethyl acetate and methanol) of the fruit of *B. karatas*, against *E. coli*, *Enterococcus faecalis* (Andrewes & Horder, 1906) Schleifer & Kilpper-Bälz, 1984, *Salmonella enteritidis* (Gaertner, 1888) Castellani & Chalmers, 1919 and *Shigella flexneri* Castellani & Chalmers, 1919. The minimum inhibitory concentration of the methanolic extract was 5 mg/mL for *E. faecalis* and 10 mg/mL for the other bacteria; and the minimum bactericide was 20 mg/mL for *E. coli and E. faecalis*, and 40 mg/mL for S. *enteritidis* and *S. flexneri* (Ayil-Gutiérrez et al., 2022).

3.4 *Bromelia laciniosa* MART. EX SCHULT. F.

The antimicrobial activity of the ethanolic extract of *B. laciniosa* leaves was evaluated by the MIC method of microdilution. The minimum inhibitory concentration (MIC) and the minimum bactericidal concentration (MBC) were determined. The ethanolic extract inhibited the growth of *S. aureus* at the lowest concentration tested, expressed antibacterial activity against *S. aureus*, as well as a potential bacteriostatic effect against *S. flexneri* (Pontes et al., 2022).

3.5 *Neoglaziovia variegata* (ARRUDA) MEZ

Investigated the gastroprotective activity and cytoprotective mechanisms of the ethyl acetate (Nv-AcOEt), hexane (Nv-Hex) and chloroform (Nv-CHCl 3) fractions of *N. variegata* leaves. All fractions at oral doses of 100, 200, and 400 mg/kg significantly decreased ethanol and ethanol/HCl-induced gastric lesions, leading to gastroprotection,

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accompanied by increased reduced glutathione (GSH) and gastric mucus (Lira et al., 2021).

They studied the extracts of *N. variegata* and evaluated their possible acaricide properties. A hexane extract of the leaves was fractionated into (5, 10 and 25 mg/ml). All fractions had harmful effects on ticks. Phytochemical analysis indicated that stigmast-5en-3-ol and stigmasterol were the most abundant responsible for the acaricide effects, making them potentially useful as alternative agents for the control of the tick *Rhipicephalus microplus* Canestrini, 1888 (Torres-Santos et al., 2021).

They evaluated the influence of seasonality on the phytochemical composition, phenolic content and antioxidant activity of *N. variegata*. Phytochemical characterization by thin layer chromatography indicated the presence of anthocyanins, anthraquinones, anthracene derivatives, flavonoids, tannins, monoterpenes, diterpenes, triterpenes, steroids and coumarins in the leaves. The extracts showed good antioxidant capacity, high concentration of phenolic compounds and a wide variety of phytochemicals. The antioxidant activity and phytochemical composition of the plant varied throughout the year (Gomes et al., 2022).

3.6 *Nidularium procerum* LINDM

They reported the first phytochemical and biological characterization in the treatment of adrenocortical carcinoma (H295R) cells from *N. procerum* extracts cultured *in vitro*. The aqueous extract improved cell adhesion and phagocytic activities and phagolysosomal formation of murine macrophages. The extracts have shown potential against adrenocortical carcinoma cells, without cytotoxicity to non-tumor cells, making it a potential candidate for alternative therapies against this tumor lineage (Gollo et al., 2020).

3.7 *Encholirium spectabile* MART. EX SCHULT. F.

They evaluated the use of *E. spectabile*, incorporated in O/A emulsion as a potential photoprotective agent, and its antioxidant activity. Emulsions containing different concentrations (1%, 2.5% and 5%) of the extract without and with the addition

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of chemical filters (octyl methoxycinnamate and benzophenone-3) were prepared and submitted to the preliminary stability test. The Q formulation showed little variation in the preliminary stability test and was selected for estimation of its UVB protection and determination of the UVA protection factor *in vitro*. The formulations remained stable during the freeze-thaw cycle, the extract despite maintaining UVA-PF and decreasing the wavelength showed an increase in SPF from 14.4 (control) to 18.8 (control + Es-HA80) (Dantas et al., 2022).

3.8 *Tillandsia fasciculata* SW., *Tillandsia shiedeana* STEUD, e *Tillandsia recurvata* (L.) L.

They evaluated extracts from species of the genus *Tillandsia* to inhibit the expression of several virulence factors without affecting bacterial growth. The species *T. recurvata*, *T. schiedeana* and *T. fasciculata* show antivirulent activity, mainly on factors related to adhesion and dispersion in *P. aeruginosa.* The organic extracts of the three species reduced violacein production without affecting bacterial growth CH3OH s-extract inhibited only 58 % to 65 % in *T. fasciculata* (Pérez-López et al., 2020).

3.9 *Tillandsia usneoides* (L.) L.

To determine the hypoglycemic effect of an aqueous extract of *T. usneoides* in normal and diabetic mice, as well as to evaluate the participation of insulin in this effect using an *in vitro* model. The results suggest that the aqueous decoction stimulates insulin secretion even in the absence of changes in the intracellular concentration of Ca2+ in RINm5F cells. The reduction of blood glucose in healthy mice at 4 and 6 h (96 ± 11.2 and 68.2 ± 1.9 mg/dl, respectively) compared to time zero (138.5 ± 5.0 mg/dl, $P < 0.05$). In diabetic mice, the aqueous extract significantly decreased blood glucose at 6 h compared to time zero (212.7 ± 3.5 and 243 ± 5.3 and mg/dl, respectively). In addition, the aqueous extract stimulated insulin secretion (20%, $p < 0.05$) without causing changes in insulin gene expression and protects RINm5F cells from streptozotocin-induced apoptosis (Espejel-Nava et al., 2020).

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They evaluated the antihyperglycemic effect of *T. usneoides* in mice and on the translocation of the plasma membrane of the glucose transporter type 4 (GLUT4) in C2C12 myoblasts and primary hepatocytes. The administration of aqueous extract decreased blood glucose by 17 and 47% at 240 and 360 min, respectively. TU-AcOEt and TU-Aqueous significantly reduced blood glucose by 240 (21 and 27%, respectively) and 360 min (21 and 38%, respectively) compared to the control group. The flavonoid (5,7,4'-trihydroxy-3,6,3',5'-tetramethoxyflavone) exhibited an antihyperglycemic effect mediated by GLUT4 translocation in muscles and hepatocytes (Miranda-Nuñez et al., 2021).

They evaluated the effect of *T. usneoides* ethanolic extract, *in vitro* and *in vivo*, in 4T1 breast cancer and B16-F10 melanoma models. *In vitro* evaluations with both cell lines showed that the extract has cytotoxic activity and induces cell death by apoptosis. *In vivo*, only in the 4T1 model, a significant decrease in tumor size was found in animals treated with the extract. The extract regulates the metabolism of 4T1 and B16-F10 cell lines in an antagonistic manner with a significant impact on the tumor microenvironment, apparently related to the enhancement of an effective antitumor immune response, which allows the reduction of 4T1 tumor but not B16-F10 (Lasso et al., 2022).

3.10 *Hechtia glomerata* ZUCC.

They identified components of organic and aqueous extracts of *H. glomerata* and tested the extracts and main isolated compounds against resistant bacteria. The extract has antibacterial activity against extended-spectrum *β*-lactamase of *E. coli* (ESBL) and three strains of *Klebsiella pneumoniae* (Schroeter, 1886) Trevisan, 1887: oxacillin, ESBL and New Delhi metallo-*β*-lactamase 1 (NDM-1), with a minimum inhibitory concentration (MIC) value of 500 µg/mL. The CHCl3/MeOH extract showed null activity against all resistant strains tested. It is possible that the activity of the CHCl3/MeOH extract against resistant bacteria was masked or inhibited by other compounds present in this extract (Stefani et al., 2019). However, the CHCl3/MeOH extract showed activity against the sensitive bacteria *S. aureus* (125 mg/mL) e *Enterococcus faecium* (Orla-Jensen, 1919) Schleifer & Kilpper-Bälz, 1984 (62,5 mg/mL) (Stefani et al., 2020).

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3.11 *Greigia sphacelata* (RUIZ E PAV.) REGEL.

They evaluated the antioxidant activity and inhibitory potential of cholinesterase from *G. sphacelata* fruit. The results showed good phenolic content and moderate antioxidant and enzyme-linked inhibitory activity against acetylcholinesterase (AChE) and butyrylcholinesterase (BChE), identifying seventy metabolites including phenolic intake, organic intake, sugar derivatives, catechins, proanthocyanidins, fats, iridoids, coumarins, benzophenone, flavonoids and terpenes. In addition, inhibitory effects against AChE and BChE suggest that natural products or food supplements derived from fruits are of interest for their neuroprotective potential (Barrientos at al., 2020).

4 CONCLUSION

From this review it is possible to conclude that the species of the Bromeliaceae family are promising for various purposes, whether pharmaceutical or industrial, highlighting the advances in traditional, phytochemical and pharmacological use. Several medicinal properties of this family have been widely used by the population for the treatment of diseases, requiring further studies on the uses discussed here, which include studies of its toxicity and safety. Due to the chemical composition of the extracts described above, they present the diversity of secondary metabolites of the species of the Bromeliaceae family, which play a crucial role in the treatment or prevention of diseases, have great medicinal properties and therapeutic applications such as antidiabetic, antioxidant, antimicrobial, anti-inflammatory, anticancer, hypoglycemic.

Pharmacological studies have been conducted primarily in cell and animal models, while investigations in humans have rarely been conducted. Thus, future investigations should focus on the bioactivity of Bromeliaceae in several human clinical studies. In summary, the bromeliads can be considered an important and valuable resource for human health, however, more research in terms of toxicity control is needed to provide a theoretical basis to explore the medicinal functions of the family's species. This review would help researchers in their search for scientific information and a source of new approaches to drug discovery in the future.

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